Title:	PM CEMS: The Current Reality of Monitoring Particulate Matter
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INTRODUCTION

New coal-fired power plant developers will soon have a new decision to make: "Should we install a particulate matter continuous emission monitor?" Many recent Prevention of Significant Deterioration (PSD) permits have required particulate matter (PM) continuous emission monitoring systems (CEMS) either as part of a compliance assurance monitoring (CAM) plan or an alternative compliance method. On Feb. 9, 2006, the Environmental Protection Agency (EPA) promulgated a revised New Source Performance Standard (NSPS) for new (built after Feb. 28, 2005), modified and reconstructed steam generating units that offer PM CEMS as an alternative to opacity and parameter monitoring requirements.

Continuous Emission Monitors are available for many pollutants: sulfur dioxide, nitrogen dioxide, oxygen, carbon monoxide, mercury and particulate matter. The newest CEMS on the market is for PM, although PM CEMS have been around for many years. Continuous monitoring of PM in stacks started in the 1960s in Germany and was a German federal requirement by the 1970s. Other European countries and Canada have been using PM CEMS for a variety of different PM sources: incinerators, pulp and paper mills, municipal and hazardous waste combustors, cement kilns and power plants. Many types of CEMS are available to monitor PM emissions.

WHY INSTALL PM CEMS AT A FACILITY?

Previously, PM CEMS may have been installed as part of a Compliance Assurance Monitoring (CAM) plan or for some other method of compliance. Often, consent decrees issued as a result of a notice of violation, required PM CEMS to ensure that emissions meet the regulatory requirements. Recently, regulations and updates to regulations have been promulgated that give the option of installing PM CEMS for compliance in lieu of other sometimes complex parametric monitoring.

Compliance Assurance Monitoring (CAM)

CAM regulations under 40 CFR Part 64 requires a specific plan for major sources of emissions that are controlled by an add-on control device. The CAM rule applies to each emission unit that meets a three-part test. The emission unit must:

1. be subject to an emission limitation or standard, and
2. use a control device to achieve compliance, and
3. have precontrol emission that exceed or are equivalent to the major source threshold (100 tons per year for PM).

CAM does have exemptions for certain emission units as follows:

1. those subject to 111 or 112 (New Source Performance Standards (NSPS) or National Emission Standards for Hazardous Air Pollutants (NESHAP)) standards promulgated after Nov. 15, 1990, since those standards have been and will be designed with monitoring that provides a reasonable assurance of compliance,
2. those subject to the acid rain program, emissions trading programs such as the acid rain program, or continuous compliance determination methods, i.e., where a regulatory requirement specifies a monitoring methods for compliance, because CAM is believed to be redundant for these units, and
3. certain municipally owned utility units, as defined in 40 CFR 72.2, that produce electricity during periods of peak electrical demand or emergency situations.

Since most coal-fired utility boilers emit more than 100 tons per year of uncontrolled PM emissions and also have controls such as an electrostatic precipitator (ESP) or fabric filter baghouse to control emissions from the boilers, PM emissions from these units often were required to submit CAM plans for PM emissions. CAM did not necessarily have to require PM CEMS, but could be other parametric monitoring such as bag-leak detectors. However, several states require PM CEMS for monitoring in lieu of other parametric monitoring. Since the revisions of NSPS Subpart Da in 2005, CAM may not be applicable to units subject to this NSPS, if the facility was constructed after Aug. 28, 2005.

New Source Performance Standards

NSPS under 40 CFR Part 60 includes Subpart Da which applies to electric utility steam generating units that are greater than 250 million British thermal units per hour (mmBtu/hr). This NSPS applies to large utility boilers for which construction is commenced after Sept. 18, 1978. Modifications were published in the *Federal Register* on May 18, 2005. The revisions include requirements that all coal-fired electric utility steam generating units that are greater than 250 mmBtu/hour of heat input that was constructed after Feb. 28, 2005, may install PM CEMS to show compliance with the limit.

Under 40 CFR Part 60, Subpart Da, for units constructed after Feb. 28, 2005, the facility must meet a PM emission limit of 0.14 pounds per megawatt-hour (lb/MW-hr) gross or 0.015 lb/mmBtu. Compliance with the 0.14 lb/MW-hr gross emission limit can only be shown with PM CEMS, (based on the formula [(PM concentration x flow)/MW]) on a daily block average of 24 one-hour averages. Compliance with the 0.015 lb/mmBtu limit is determined by an initial performance test, continuous opacity monitoring system (COMS), parametric monitoring for ESPs or fabric filter, and an annual performance test. Alternatively, PM CEMS using daily block averages of 24 one-hour averages may be used.

Consent Decrees

During the past several years, the EPA or state agencies have required several coal-fired boilers to install PM CEMS as part of a consent decree order. Tampa Electric Company, Virginia Electric Power Company, Wisconsin Electric Power Company, South Carolina Public Service Authority, Illinois Power Company/Dynegy Midwest Generation, Inc., and Minnkota Power Cooperative, Inc./Square Butte Electric Cooperative have all been issued Clean Air Act violations and a consent decree that requires PM CEMS to continuously monitor PM emissions from their facility (or multiple facilities). For many of these facilities, the compliance date has not yet passed, however, for some; at least one PM CEMS was required to be installed before the date of this paper.

Compliance with New Regulations and Operational Flexibility

Existing electric generating units have many new challenges facing them in the coming years. With the Clean Air Interstate Rule (CAIR) and Best Available Retrofit (BART) requiring sulfur dioxide (SO_2) and nitrogen oxides (NO_x) control, and the Clean Air Mercury Rule (CAMR) requiring mercury reductions, a large number of units will be installing wet flue gas desulfurization (FGD) scrubbers, controlling mercury emissions, and even controlling sulfuric acid mist emissions. Some units may consider upgrading an undersized ESP. Economic incentives exist to burn lower cost opportunity fuels with the coal (e.g., petroleum coke, tire derived fuel, biomass). PM CEMS in these applications are more than a compliance monitoring requirement; they are also an operational flexibility tool.

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Monitoring particulate emissions after the wet scrubber eliminates all the problems associated with opacity monitoring upstream of the wet FGD. Short-term six-minute problems associated with opacity monitoring are eliminated. The cost of six duct diameters of straight duct between the ESP and FGD to locate the opacity monitors according to Performance Specification 1 (PS-1) requirements is eliminated. Operating COMS on ducts is much more difficult, burdensome and time-consuming than on a stack. Most plants will need multiple duct opacity monitors. The manpower needs for servicing and auditing the COMS are going to escalate.

Mercury monitoring and control starts on coal-fired units in a few years. Injecting additives and sorbent compounds may be necessary or desirable depending on the coal type. Compounds injected before the ESP could affect operation and ESP efficiency resulting in changes in duct opacity and particulate emissions. Mercury control compounds and particulate can be removed by the wet scrubber and thus not emitted from the stack. Monitoring particulate emissions in the wet stack will allow the plant the flexibility to control mercury emissions as needed. Unless particulate emissions are monitored, units with injection will have to develop new CAM plans for particulate.

Installation of wet scrubbers after selective catalytic reduction systems has caused an increase in sulfuric acid mist emissions especially on units using Eastern coals. The blue plume effect has caused a panic to invent strategies to control sulfuric acid mist. Injecting additives and sorbent compounds into the boiler or ducts to control SO_3 can cause opacity issues for a COMS installed upstream of the wet scrubber. This problem is most acute for hot side ESP where some control compounds must be injected after the ESP. When these SO_3 control compounds are injected after the ESP, high opacity readings can be recorded by a COMS installed before the wet scrubber. These SO_3 control compounds are readily removed by the wet scrubber and are not found as stack particulate emissions. A PM CEMS in the wet stack will allow the plant to demonstrate compliance and control SO_3 as needed.

Some units have undersized ESPs or have ESPs that was not originally designed for the fuels that are now being used. Some companies believe that the ESP needs to be upgraded when the wet scrubber is added. The new high efficiency scrubbers remove 90 percent or more of the particulate that passes through the ESP. A unit with a marginal ESP and a new wet scrubber will be well within the particulate emission limit even if the opacity monitored upstream of the new wet scrubber is above the opacity limit. Building additional particulate removal into the new wet scrubber is less costly then an ESP upgrade. A PM CEMS in the wet stack will allow the plant to avoid a costly ESP upgrade.

Blending fuels can cause changes in opacity that limit fuel flexibility by causing excess opacity upstream of the wet scrubber. Each new fuel or combination of fuels, in theory, requires a new CAM plan. Using a PM CEMS allows for the use of all fuels and fuel blends as long as compliance with the particulate emission limit is maintained in the wet stack after the wet scrubber.

TYPES OF PM CEMS

Several types of technologies are available for the continuous measurement of PM. Several technologies have been used for many years, while some are still in testing stage. The various technologies that are available for the continuous measurement of PM are listed below.

<u>Light Scattering</u> — Light falling upon particles in a gas stream are scattered in various directions. This method includes a light source and a sensor that detects that amount of light scattered in a specific direction. The light is pulsed. The amount of light scattered is proportional to the PM concentration.

<u>Beta Ray Attenuation</u> — The attenuation of beta rays is proportional to the mass of material present. This method is also called a Beta Gauge and includes a beta ray source (typically Carbon-14) and a filter media in form of a tape that is fed through the instrument at predetermined intervals. It operates in batch mode by taking a beta count of clean filter media, collecting the PM on the media, taking a second beta count on the media after sample collection, and comparing the before and after beta counts. The difference between the beta counts is proportional to the PM

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concentration. The method includes an 8-9 minute sample, a pre-baseline beta ray measurement and a post-sample measurement.

Probe Electrification — The friction of particles impacting a sensor generates a small electrical current in the sensor and a small electrical current is also generated when charged particles pass near but do not impact a sensor. The electrical current produced by the friction of impacting particles is proportional to the momentum of the particles. This has been primarily used for fabric filter bag leak detectors.

Light Extinction — Light passing through a gas steam is attenuated by the particles in the stream. The comparison of the intensity of the light sources to the intensity of light at the receptor provides an indication of the concentration of particles in the gas stream. Receptors can be either located at the opposite side of the stack (single-pass) or on same side of the stack as the light source (double-pass). Instrument is called a transmissometer are used as COMS.

Optical Scintillation — Variations in the amplitude of light received by a sensor is caused by particle in a gas stream. The greater the amplitude (scintillation) at the sensor, the greater the concentration of particles in the gas stream.

Harmonic Oscillation — The vibration or oscillation of a tube (or rod) fixed at one end is proportional to the mass of the tube. A filter attached to the end of a small tube with an electronic sensor that measures the vibration of the tube (TEOM). As the mass increases in the tube and the filter the frequency of oscillation is altered. The mass collected on the filter can be determined by comparing the baseline frequency to the frequency at any time. Once the filter becomes saturated (few hours to a few days), the instrument must be taken off line for filter replacement.

COMPARISON OF PM CEMS TECHNOLOGIES

As there are several types of technologies available for the continuous measurement of PM, each has qualities that may be better for your facility. Table 1 displays many characteristic of the PM CEMS technologies. A description of the parameters is discussed below the table.

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Table 1

PM Technologies Comparison[1]

Criterion	PM Monitor Principle of Operation					
	Light Scattering	Beta Attenuation	Probe Electrification	Light Extinction	Optical Scintillation	Harmonic Oscillation
Method of Measurement	Amount of light scattered by particles	Amount of beta rays attenuated by particles	Electrical current generated by particle friction and charge	Amount of light attenuated by particles	Variations in amplitude of light due to particles	Change in oscillation due to mass collected on filter
Installation Configuration	In situ	Extractive	In situ	In situ	In situ	Extractive
Continuous or Batch	Continuous	Batch	Continuous	Continuous	Continuous	Batch
Extent of Use	Wide-Spread Use	Wide-spread use	Used a fabric filter bag leak detectors	Used as COMS	Limited	Limited
History of Use	Long history	Long history	Long history as bag leak detectors	Long history of use as COMS	Short history	Short history
Particle Characteristics	Highly dependent	Less dependent	Highly dependent	Highly dependent	Highly dependent	Not dependent
Interferences	Water droplets	None	Electrical fields	Water droplets	Water droplets	None
Other comments	May not be appropriate for wet-scrubber-controlled sources		May not be appropriate for sources controlled with ESPs and Difficult to correlate to mass	May not be appropriate for wet scrubber-controlled sources and Difficult to correlate to mass	May not be appropriate for wet scrubber-controlled sources	Current designs suitable for short-term use only (up to approximately 3 days)
Documented Problems Meeting Correlation Criteria in Performance Specification 11	No	No	Yes	Yes	No	No

[1] Table from *Status of Particulate Matter Continuous Emission Monitoring Systems for Application to Electric Utility Steam Generating Units*, USEPA, OAQPS, September 2004.

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Method of Measurement: All methods are indirect measurements of PM except for harmonic oscillation, which measures PM concentration directly. All others measure concentration based on physical properties of the PM in the gas stream. The indirect methods must correlate the concentration to the physical property measured by the method.

Installation Configuration: In-situ methods can analyze the sample in the stack, while extractive methods must transport the sample to the analyzer outside the stack. The extractive systems may have additional mechanical parts for the transport to keep sample at the same parameters as it enters the analyzer.

Operating Mode: The PM CEMS may operate continuously, or in a series of batch cycles. The batch mode includes a sample volume measuring system that must is calibrated periodically. Typically, batch type CEMS have more parts, which may require more maintenance than a true continuous CEMS. Correlation testing is also more difficult with batch mode CEMS as the sample must coincide with the stack test.

Extent of Use and History of Use: Self-explanatory.

Effects of Particle Characteristics: All PM CEMS except for the type that directly measures the mass (Harmonic Oscillation) rely on particle characteristics. Drift or calibration shifts are more likely to occur in these methods. Optical instruments (light scattering, extinction and scintillation) are more sensitive than non-optical methods (beta gauge, probe electrification, harmonic oscillation).

Interferences: Optical instruments may have interferences from other light sources. Water droplets in a gas stream, such as those following a wet FGD system can interfere with PM CEMS with optical instruments. Therefore, optical systems are generally limited to those dry systems, unless the system extracts the sample and heats it to eliminate the excess moisture.

Ability to Pass the Correlation Criteria in the Performance Specification 11[2] for PM CEMS: Performance Specification 11 (PS-11) establishes procedures for selecting, installing, and operating PM CEMS. One requirement of PS-11 is a correlation test which includes a minimum of 15 test runs during a time when the PM CEMS is analyzing at the same time as reference method measurements of PM concentration is occurring. The reference method may be EPA Method 5, 5i or 17. A wide range of PM concentrations should be tested to ensure that the correlation regression analysis is accurate.

CHOOSING THE RIGHT PM CEMS FOR A FACILITY

As stated previously, some types of PM CEMS are not appropriate for use with certain other add-on control device chains. Optical instruments (light scattering, light extinction, optical scintillation) should be avoided on units controlled with a wet FGD unless the PM CEMS can remove the water droplets by heating the sample sufficiently. Units controlled by ESPs should not use probe electrification PM CEMS because they respond to particle charge.

The availability of space for a PM CEMS may also dictate which type of CEMS a facility installs. An in situ type CEMS (light scattering, light extinction, optical scintillation) takes up a lot less space than an extractive CEMS. Extra space is required for the additional equipment required for transporting, heating, and analyzing the volume of the sample.

Placement of the PM CEMS probe should be reviewed prior to final selection of the CEMS. The location is critical because a representative sample must be collected. Flow disturbances should be avoided and the probe should be located at least two duct (or stack) diameters upstream of any disturbance or 8 duct diameters downstream of any

[2] Performance Specification 11-Specifiations and Test Procedures for Particulate Matter Continuous Emission Monitoring Systems at Stationary Sources, 40 CFR Part 60, Appendix B.

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disturbance. This is not always possible in existing units, so the location of the probe could cause problems. In addition to the location along the duct (or stack), the location of the probe within the cross-section of the duct is important. Some stratification of the PM occur across the duct or stack, however it is not as prevalent as with gaseous pollutants. Since correlation tests require sampling the same exhaust gas for the reference method as the CEMS, some priority of location near sampling ports should be considered.

PLANT OPERATIONAL CHALLENGES THAT WERE SOLVED BY USING PM CEMS

Case 1

Western Kentucky Energy (WKE) operates the Henderson Municipal Power & Light (HMPL) II plant for the city of Henderson, Kentucky. In 1995, a magnesium-promoted wet lime FGD system was installed for SO_2 control. When the wet FGD was installed, the COMS had to be relocated to the duct upstream of the FGD and after the ESP.

Periodically, the opacity readings upstream of the FGD approached the opacity limit. When this occurred, operations personnel took measures to reduce the upstream opacity so that the limit would not be exceeded. The plant noted that although the upstream opacity readings were high, the stack exit opacity was low. Periodic stack testing results showed the PM emissions to be well below the PM standard even when the upstream opacity readings were high. As the operational measures to control upstream opacity readings became burdensome to the plant, the plant manager decided to investigate ways to eliminate opacity monitoring upstream of the scrubber.

WKE implemented a plan to eliminate the COMS upstream of the wet FGD by directly monitoring particulate emissions in the wet stack. WKE investigated PM emission monitors and found that the beta gauge PM CEMS were successfully monitoring PM emissions in several wet scrubber stacks at plants across the country. WKE devised a plan to monitor compliance with the PM standard in the wet stack in exchange for not reporting continuous opacity compliance as measured upstream of the wet FGD.

With single point sampling, the effects from particulate stratification on the monitor's ability to accurately measure particulate emissions across the range of operation was an initial concern. To gain confidence that particulate stratification would not be an issue, a stratification test program was devised and initially conducted. In order to conduct the stratification test, the unit was set up to be operated in three separate conditions. Although the wet FGD was obviously removing a significant portion of the particulate matter in the gas stream, the FGD could only be operated in an "on" or "off" mode with a minimum of one recycle pump and no additional "turn down." As such, the only way to attempt to vary the particulate loading beyond the FGD was by unit loading (megawatts) and by fuel. The "low" particulate mass condition was measured during low unit load with a "typical" fuel. The "mid" condition was measured during normal high unit load operation with "typical" fuel, and the "high" condition was measured during maximum unit loading with a high ash fuel.

From particulate loading test values determined from stack traverses at the three conditions, the best location was selected for the probe in order to accommodate accuracy requirements across the range of unit operation. A new port was installed in the flue gas liner in order to locate the probe at the most representative point.

In 2005, regulatory approval was obtained from the state agency and the U.S. EPA regional office. In early 2006, the Title V permit was modified, and the PM CEMS was installed and certified. Following certification, it was discovered that pluggage in the monitor and the probe was occurring. The problem was addressed by varying the temperatures within the system adhering to limits of the EPA monitoring methodology. After some investigating, it was discovered that the mist eliminators in the FGD had become blocked resulting in excessive carryover. As a result, the particulate monitor output is now utilized by plant operation personnel as an additional indication of maintenance issues within the FGD.

During 2006 the plant has operated using the beta gauge PM CEMS as the PM continuous compliance determination method. The plant is no longer burdened by operational restrictions that were created by the opacity readings upstream of the FGD.

Case 2

An electric utility company with plants in Ohio is installing several wet scrubbers. The plant property has limited space, and the scrubbers are being built in the area between the existing ESP and the stacks. The length of straight duct between the ESPs and scrubbers does not meet the citing criteria for compliance opacity monitors (PS-1 requires four duct diameters upstream of the COMS and two duct diameters downstream of the COMS). Because of turning vanes in the duct, only a few feet of straight duct exists between the ESP and scrubber booster fans. Furthermore, the units have split ESPs and require two COMS per unit.

This utility decided to investigate using PM CEMS in lieu of COMS for the particulate compliance determination method. Regulatory approvals have been negotiated with the state agency and the U.S. EPA regional office to use PM CEMS as an alternative to installing COMS upstream of the new scrubber.

SUMMARY

PM CEMS may be a reality for many coal-fired utility plants in the very near future. Revised regulations and the availability and reliability of PM CEMS are making them a very valid choice for compliance demonstrations for PM emission limitations and for CAM requirements. Several different types of PM CEMS are available and the type of CEMS selected for a facility depends on the type of exhaust (wet or dry) the space available for the CEMS, operability of the CEMS by the plant personnel, and many other parameters.

Common types of CEMS include in-situ and extractive types. In-situ types are optical types and depend on light scattering, light attenuation or affects to the amplitude of light. Extractive types included beta gauge and harmonic oscillation. Each type of CEMS has characteristics that may have disadvantages or advantages over other types of CEMS at various facilities.

PM CEMS may solve compliance monitoring issues at a facility, but setup may be difficult. Some of the CEMS experience problems passing the correlation criteria of the performance specification or have problems setting up the test at different particulate loading.

Owners and operators of coal-fired utility plant should consider all aspects of PM CEMS before deciding to install a PM CEMS. If a PM CEMS is required or selected for a plant, the various characteristics of each type of PM CEMS should be examined to determine which type would work best at the plant.